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Title of invention: Object-detecting device and object-detecting method

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Name of document	Claims	1
Name of document	Specification	1
Name of document	Figures	1
Name of document	Summary sheet	1

Claims

1. A type of object-detecting device characterized by the fact that it has the following means:

an image-pickup means that captures the image from the front of the vehicle itself,

an image judgment means that performs image processing for the image captured with said image-pickup means (hereinafter to be referred to as the "picked-up image") and judges whether said picked-up image was captured when the vehicle itself was balanced,

and an object position computing means that performs the following operation: when it is judged by said image judgment means that said picked-up image was captured when the vehicle itself was not balanced, the position of the object in said picked-up image is determined based on the picked-up image captured when the vehicle itself was balanced.

2. The object-detecting device described in Claim 1 characterized by the following facts:

it also has an acceleration-computing means that computes the acceleration of the object present in said picked-up image (hereinafter to be referred to as "image acceleration");

said image judgment means judges that said picked-up image corresponding to zero image acceleration as computed by said acceleration computing means is an image captured when the vehicle itself was balanced.

3. The object-detecting device described in Claim 2 characterized by the following facts:

it also has a velocity computing means that performs image processing for the picked-up image captured with said image pickup means and computes the velocity of the object present in said picked-up image in the vertical direction of the image (hereinafter to be referred to as "image velocity");

said image judgment means judges that said picked-up image, which has zero image acceleration as computed by said acceleration computing means, and which has positive or negative image velocity as computed by said velocity computing means is an image captured when the vehicle itself was balanced.

4. The object-detecting device described in any of Claims 1-3 characterized by the fact that

it also has an object information computing means that performs the following operation: when it is judged by said image judgment means that said picked-up image was captured when the vehicle itself was not balanced, the size of the object present in said picked-up image is computed based on the picked-up image captured when the vehicle itself was balanced, and based on the computing result, the distance from said image pickup means to the object present in said picked-up image is computed.

5. The object-detecting device described in Claim 4 characterized by fact that

said object position computing means performs the following operation: when it is judged by said image judgment means that said picked-up image was captured when the vehicle itself was not balanced, based on the distance from said image pickup means to the object present in said picked-up image computed by means of said object information computing means, the vision axis of said image pickup means at the time when said picked-up image was captured is computed, and based on the computed vision axis of said image pickup means, the position of the object in the image is computed.

6. An object-detecting method characterized by the following facts:

the image from the front of the vehicle itself and captured by an image pickup means (hereinafter to be referred to as the "picked-up image") is subjected to image processing, and a judgment is made as to whether said picked-up image was captured when the vehicle itself was balanced;

when it is judged that said picked-up image was captured when the vehicle itself was not balanced, the position of the object present in said picked-up image is computed based on the picked-up image captured when the vehicle itself was balanced.

[Document name] Specification

Title of the invention: Object-detecting device and object-detecting method

Technical field

[0001]

The present invention pertains to an object-detecting device and an object-detecting method for detecting the presence of an object the front of the vehicle itself.

Background technology

[0002]

Patent Reference 1 disclosed a type of position-detecting device characterized by the following facts: plural objects are extracted from the images captured by an onboard camera; based on the variation over time of the position in y-direction (height) of said plural objects, correction of the y-coordinates of the objects is performed taking into consideration the pitching and other behavior of the vehicle. As a result, it is possible to detect the position of each object by excluding the influence of the pitching and other behavior of the vehicle.

[0003]

[Patent Reference 1] Japanese Kokai Patent Application No. 2001-84497

Disclosure of the invention

Problems to be solved by the invention

[0004]

However, because detection of the y-coordinate is performed based on the variation over time of the position of the object in y-direction, it is impossible to detect variation in the position of the object due to pitching that often takes place due to passengers, cargo, etc. This is undesirable.

Means for solving the problems

[0005]

This invention is characterized by the following facts: the image from the front of the vehicle itself and captured with an image pickup means (hereinafter to be referred to as the "picked-up image") is subjected to image processing, and a judgment is made as to whether said picked-up image was captured when the vehicle itself was balanced; when it is judged that said picked-up image was captured when the vehicle itself was not balanced, the position of the object in said picked-up image is computed based on the picked-up image captured when the vehicle itself was balanced.

Effects of the invention

[0006]

According to the present invention, a judgment is made as to whether the picked-up image was captured when the vehicle itself was balanced; if it is judged that the picked-up image was captured when the vehicle itself was not balanced, the position of the object present in said picked-up image is computed based on the information about the object computed from the picked-up image captured when the vehicle itself was balanced. As a result, even when pitching often takes place due to passengers or cargo, it is determined that said picked-up image was captured when the vehicle itself was not balanced, and it is possible to compute the position of the object in the image correctly.

Optimum embodiment of the invention

[0007]

Figure 1 is a block diagram illustrating an example of the constitution of an embodiment of the object-detecting device in the present embodiment. Said object-detecting device (100) is mounted on board the vehicle, and it includes camera (1), image memory (2), microcomputer (3), and display unit (4). Said camera (1) is arranged at the front of the vehicle, and it takes pictures at a constant time interval Δt. Said image memory (2) converts the image captured with camera (1) to digital data and stores it. Said microcomputer (3) reads the digital image stored in image memory (2). As will be explained later, the size of the object in real space and the distance to the object are detected, taking into consideration the pitching of the vehicle. Said display unit (4) displays the detected object in a bird's-eye-view mapped downward onto a map with the vehicle itself at the center.

[0008]

Also, in the present application example, it is assumed that in the image captured with camera (1), only one moving object, such as another vehicle, is present, and the real-space size of the object present in the image has a width that can be detected on the image.

[0009]

Figure 2 shows an example of change in the position of the object present the front of the vehicle in the picked-up image when pitching of the vehicle takes place. As shown in Figure 2(a), assuming the deviation angle to be θo when the object is viewed from the camera vision axis θ with respect to the horizontal direction, y-coordinate value yo in the picked-up image when the vehicle is balanced (to be defined later) is computed using the following Equation (1):

$$yo = \alpha\theta o \cdots (1)$$

Here, α is a constant that can be uniquely computed from the image pickup element size, focal distance, etc., of camera (1) (hereinafter to be referred to as the "camera parameters").

[0010]

In this case, when pitching of the vehicle takes place, and the pitching angle in this case is θp, y-coordinate yo' of the object in the image is computed using the following Equation (2):

$$yo' = \alpha\theta o' = \alpha(\theta o + \theta p) = yo + \alpha\theta p \cdots (2)$$

That is, the change in the y-coordinate of the object in the image when pitching takes place can be seen to be proportional to the size of pitching angle θp. Consequently, Figure 3 shows the relationship of pitching angle θp and the y-axis acceleration of the object in the image, that is, the vertical acceleration of the image (image acceleration).

[0011]

As shown in Figure 3, characteristic curve (3a) shows the up/down periodic movement (periodic movement (3a)) due to pitching when pitching takes place; characteristic curve (36) shows the change in image velocity over time (image velocity (3b)); and characteristic curve (3c) shows the change in image acceleration (image acceleration (3c)) over time. As shown in Figure 3, when image acceleration (3c) is zero, image velocity (3b) is maximum or minimum, and periodic movement (3a) is at the inflection point. Because the inflection point of periodic movement (3a) shows the point at which the vehicle is balanced, it is possible to judge that an

image with an image acceleration (3c) of zero is one captured when the vehicle itself was balanced when pitching of the vehicle itself took place.

[0012]

Also, in this embodiment, edge extraction processing for the picked-up image allows the well-known gradient method and block matching method to be adopted to compute the optical flow, and the velocity of the object present in the image is detected. As a result, said image velocity (3b) and image acceleration (3c) are detected. The edge extraction processing and the optical flow computation processing are well-known technologies, and will not be explained again.

[0013]

Based on the image for which image acceleration (3c) in the y-direction is zero for the object detected on the image, that is, the image captured when the vehicle itself was balanced (balanced image), it is possible to compute the y-coordinate of the object in the image, to be explained later, the width of the object in real space (the size of the object), and the distance from camera (1) to the object, that is, distance D from the focal position of camera (1) to the object. Figure 4 shows an example of the situation in which the image balanced is used to compute the y-coordinate of the object in the image, the width of the object in real space, and the distance between the focal position of camera (1) and the object. Figure 4(a) shows a side view of the object, and Figure 4(b) shows an top view of the object.

[0014]

As shown in Figure 4(a), using vision axis θ of camera (1) and apparent angle of the object θo that can be detected in the image, the y-coordinate of the object in the image can be computed using the following Equation (3).

$$y = \alpha(\theta + \theta o) \cdots (3)$$

Also, assuming the pre-measured camera mounting height to be H, the vision axis of camera (1) to be θ, and the apparent angle of the object to be θo, distance D from the focal position of camera (1) to the object is D can be computed using the following Equation (4).

$$D = H / \tan(\theta + \theta o) \cdots (4)$$

[0015]

Width Ws of the object is then computed. As shown in Figure 4(b), based on the relationship between image width xw and lateral angle θx of the object, the following Equation (5) is obtained.

$$xw = \beta\theta x \cdot \cdot \cdot \quad (5)$$

Here, β is a constant that can be uniquely computed from the camera parameters.

[0016]

Consequently, using Equation (5), one can compute width Ws of the object using the following Equation (6).

$$Ws = \theta x \cdot D = xw / \beta \cdot D \cdot \cdot \cdot \quad (6)$$

Consequently, based on the image balanced, it is possible to compute the y-coordinate of the object, width Ws of the object, and distance D from the focal position of camera (1) to the object using Equations (3), (4) and (6).

[0017]

However, when pitching of the vehicle takes place often, the vision axis θ of camera (1) changes according to the pitching angle, and the magnitude of the change is unclear. Consequently, in this case, it is impossible to compute the y-coordinate of the object, width Ws of the object, and distance D from the focal position of camera (1) to the object using the aforementioned processing. Consequently, for an image for which image acceleration (3c) is not zero, these can be computed as follows.

[0018]

First of all, the balanced images, captured at different times T1 and T2, of the presence of the object judged to be the same object in the image for which image acceleration (3c) is not zero, are read from image memory (2). Whether the objects detected in the images with a non-zero image acceleration (3c) are the same object can be judged by checking whether they have a similar velocity in the images and a similar shape after edge extraction processing and detection. Also, camera (1) in this embodiment is a high-speed camera, and it takes consecutive pictures from the front of the vehicle at a minute prescribed time interval Δt, such as 2 ms. The precondition is that the balanced images captured at different times T1 and T2 must contain the

same object detected in the image with non-zero image acceleration (3c). The following explanation is given based on this precondition.

[0019]

It is possible to represent the distances D1 and D2, between the focal position of camera (1) and the object in the images balanced at times T1 and T2, with the following Equations (7) and (8) using Equation (4) by utilizing the apparent angles $\theta o1$ and $\theta o2$ of the object at said times, respectively.

$$D1 = H / \tan(\theta + \theta o1) \cdots (7)$$
$$D2 = H / \tan(\theta + \theta o2) \cdots (8)$$

[0020]

Also, widths Ws of the object at times T1 and T2 can be represented with the following Equations (9) and (10) using Equation (6) from the lateral angle $\theta x1$ and $\theta x2$ of the object at said times, respectively.

$$Ws = \theta x1 \cdot D1 \cdots (9)$$
$$Ws = \theta x2 \cdot D2 \cdots (10)$$

As a result, by substituting Equations (7) and (8) into Equations (9) and (10), respectively, one can obtain the following Equations (11) and (12):

$$Ws = \theta x1 \cdot H / \tan(\theta + \theta o1) \cdots (11)$$
$$Ws = \theta x2 \cdot H / \tan(\theta + \theta o2) \cdots (12)$$

[0021]

In Equations (11) and (12), when an image from far the front of the vehicle is captured with on-board camera (1), it is possible to set approximately $\theta \approx 0$, $\theta o1 \approx 0$, and $\theta o2 \approx 0$. Consequently, in Equation (11), one has $\tan(\theta+\theta o1) \rightarrow \theta + \theta o1$. In Equation (12), one has $\tan(\theta+\theta o2) \rightarrow \theta + \theta o2$. As a result, Equations (11) and (12) are represented by following Equations (13) and (14), respectively. Based on this relationship, one can obtain the following Equations (15) and (16):

$$Ws = \theta x1 \cdot H / (\theta + \theta o1) \cdots (13)$$
$$Ws = \theta x2 \cdot H / (\theta + \theta o2) \cdots (14)$$
$$Ws \cdot (\theta + \theta o1) = \theta x1 \cdot H \cdots (15)$$
$$Ws \cdot (\theta + \theta o2) = \theta x2 \cdot H \cdots (16)$$

[0022]

Here, by subtracting Equation (16) from Equation (15), the following Equation (17) can be obtained, and it is possible to compute width Ws of the object.

$$Ws = H \cdot (\theta x1 - \theta x2) / (\theta o1 - \theta o2) \cdots (17)$$

As a result, even when pitching of the vehicle takes place, and the vision axis θ of camera (1) for the images captured in this case becomes unknown, it is still possible to compute width Ws of the object from the camera mounting height H that can be detected in the two images balanced at different times for the same object, as well as from θo1, θo2, θx1 and θx2 that can be measured from the images.

[0023]

Based on the width Ws of the object computed in this case, distance D from the focal position of camera (1) to the object in the images captured during said pitching state, it is possible to derive the following Equation (18) using Equation (6).

$$D = Ws / \theta x = Ws \cdot \beta / xw \cdots (18)$$

As a result, by means of Equation (4), vision axis θ of camera (1) can be computed with the following Equation (19) using distance D from the focal position of camera (1) to the object.

$$\theta = \mathrm{atan}(H / D) - \theta o \cdots (19)$$

As a result, even when there is change in vision axis θ of camera (1) when pitching of the vehicle takes place, it is still possible to compute width Ws of the object and vision axis θ of camera (1) based on the images balanced [captured] at different times T1 and T2. Since vision axis θ of camera (1) has been computed, it is possible to compute the y-coordinate of the object in the image using Equation (3).

[0024]

Based on the y-coordinate in the image computed using the aforementioned processing, for example, it is possible to mark the object on a bird's-eye-view map displayed on display (4). As a result, even when pitching of the vehicle takes place, it is still possible to reliably correct for

the deviation of the object in the y-direction in the image due to pitching, and to display the obtained result in a bird's-eye-view map.

[0025]

Figure 5 is a flow chart illustrating the process of object-detecting device (100) in this embodiment. The processing shown in Figure 5 is carried out as follows: the ignition switch of the vehicle is turned ON, the power supply for the object-detecting device is turned ON, and the program is started that is used to execute the processing with microcomputer (3). In step S10, the picked-up images captured with camera (1) and stored in image memory (2) are read, and process flow then continues to step S20.

[0026]

In step S20, edge extraction processing is performed on any image that is read as described above to compute the optical flow. As a result, image velocity (3b) and image acceleration (3c) are computed, and process flow continues to step S30. In step S30, determination is made as to whether the computed image acceleration (3c) is zero. If it is determined that the computed image acceleration (3c) is zero, the read image was judged to have been captured when the vehicle was balanced, and process flow continues to step S40. In step S40, as explained above, the y-coordinate of the object, width Ws of the object, and distance D from the focal position of camera (1) to the object are computed by means of said Equations (3), (4) and (6).

[0027]

On the other hand, when it is determined that the computed image acceleration (3c) is not zero, it is judged that the read image was captured when pitching was taking place, and process flow continues to step S50. In step S50, the images captured in the balanced state at different times T1 and T2 and containing the same object as said object detected in the picked-up image are read from image memory (2). Process flow then continues to step S60. Width Ws of the object in real space, distance D from the focal position of camera (1) to the object, and vision axis θ of camera (1) are then computed by means of Equations (17), (18), and (19). Then, process flow continues to step S70, and the y-coordinate of the object is computed using Equation (3).

[0028]

Then, process flow continues to step S80. In this step, based on the y-coordinate of the object and width Ws of the object in real space, the detected object is mapped on a bird's-eye-view map, and this is displayed on display unit (4). Process flow then continues to S90. In step

S90, a judgment is made as to whether the ignition switch of the vehicle is OFF. If it is not OFF, flow returns to step S10 and the aforementioned process is repeated. If it is OFF, the processing comes to an end.

[0029]

In the present embodiment explained above, the following effects can be realized.

(1) Said image acceleration (3c) of the image of the object is computed, and the image for which image acceleration (3c) for the image of the object is found not to be zero is judged to be an image captured when the vehicle was pitching. As a result, it is possible to detect the occurrence of pitching without carrying a device for detecting the posture of the vehicle or another device for detecting pitching, so that the cost of the device can be reduced with this constitution.

(2) For the image captured when no pitching of the vehicle takes place, that is, for an image captured in the balanced state, distance D from the focal position of camera (1) to the object is computed based on camera mounting height H, vision axis θ of camera (1), and apparent angle of the object θo, and object width Ws can be computed based on image width xw, object lateral angle θx, and the distance from the focal position of camera (1) to the object. As a result, the distance to the object and the size of the object can be detected without any need for a dedicated sensor, and the device can be realized with a simple constitution.

[0030]

(3) When pitching of the vehicle takes place, width Ws of the object in real space is computed based on the images captured in the balanced state at different times T1 and T2 determining that the object is the same as that detected in the image when pitching took place, and distance D from the focal position of camera (1) to the object and vision axis θ of camera (1) are computed based on the computing result. As a result, even when vision axis θ of camera (1) is uncertain when pitching takes place, it is still possible to correctly compute the vision axis θ of camera (1), the distance to the detected object, and the size of the detected object.

[0031]

(4) Also, when pitching of the vehicle takes place, the y-coordinate of the object in the image is computed based on vision axis θ of camera (1) and the object is mapped on the bird's-eye-view map and displayed on display unit (4). As a result, even when pitching of the vehicle takes place, it is still possible to reliably correct for deviation in the y-direction in the image of the object due to pitching, and to display the corrected result on the bird's-eye-view map.

[0032]

Also, the following modifications are allowed.

(1) In the aforementioned embodiment, in order to detect image velocity (3b) and image acceleration (3c), edge extraction processing is performed on the picked-up image, and the optical flow is computed. However, other schemes can be adopted to detect image velocity (3b) and image acceleration (3c).

[0033]

(2) In the aforementioned embodiment, the image for which image acceleration (3c) is zero is judged to be an image captured when the vehicle itself was balanced. However, it is also possible to judge that an image for which image velocity (3b) is plus or minus and image acceleration (3c) is zero is an image captured when the vehicle itself was balanced. In this way, even when the characteristics on the extension side and those on the contraction side are different due to the vehicle suspension, it is still possible to correctly detect the balance state of the vehicle.

[0034]

(3) In said embodiment, as an example, it is assumed that there is only one moving object in the image captured with camera (1). However, the present invention is not limited to this scheme. For example, a scheme can be adopted in which plural moving objects are present in the image. In this case, said processing is performed for all of the objects detected in the image, and the y-coordinate of an object, width Ws of the object in real space, and distance D from the focal position of camera (1) to the object are then computed.

[0035]

(4) In said embodiment, as an example, when pitching of the vehicle takes place, vision axis θ of camera (1) becomes unclear, so that width Ws of the object in real space is computed, and distance D from the focal position of camera (1) to the object, vision axis θ of camera (1), and the y-coordinate of the object in the image are computed. However, the present invention is not limited to this scheme. For example, a scheme can also be adopted in which even when mounting position of camera (1) deviates and vision axis θ of camera (1) becomes unclear, the aforementioned method is used to compute width Ws of the object in real space, distance D from the focal position of camera (1) to the object, vision axis θ of camera (1), and the y-coordinate of the object in the image.

[0036]

(5) In said embodiment, as an example, the detected object is mapped on a bird's-eye-view map for display on display unit (4). However, the present invention is not limited to this scheme. For example, a scheme can be adopted in which the object is mapped on a planar map or on another type of map for display.

[0037]

In the following, an explanation will be given regarding the correlations between the structural elements of the embodiments and the claims. Said camera (1) corresponds to the image pickup means, and microcomputer (3) corresponds to the image judgment means, object position computing means, acceleration computing means, velocity computing means, and object information computing means. Also, as long as the characteristic features of the present invention are observed, the present invention is not limited to the aforementioned embodiments.

Brief description of the figures

[0038]

Figure 1 is a block diagram illustrating an example of the constitution of an embodiment of the object-detecting device.

Figure 2 is a diagram illustrating an example of change in the position of the object present the front of the vehicle and present in the picked-up image when pitching of the vehicle takes place.

Figure 3 is a graph illustrating the relationship between pitching angle θp, the velocity in the y-direction of the object in the image, and the acceleration in the y-direction of the object in the image.

Figure 4 is a diagram illustrating an example of the situation when the images that have been captured balanced are used to compute the height and width of the object in real space, and the distance from the focal position of camera (1) to the object.

Figure 5 is a flow chart illustrating the processing performed by object-detecting device (100).

Explanation of symbols

[0039]

100	Object-detecting device
1	Camera
2	Image memory
3	Microcomputer